[024] U.S. Patent No. 7,144,533 to Koslow teaches ~~s~~ a nanofiber mats coated with microbiological interception enhancing agent (such as a cationic metal complex) that provide greater than 4 LRV of viral removal and 6 LRV of bacterial removal.

[025] U.S. Patent Publication No. 2009/0199717 to Green teaches a method to form an electrospun fiber layer carried by the substrate layer, the fine fiber layer including a significant amount of fibers with a diameter of less than 100 nanometers.

[026] Bjorge et al. in Desalination 249 (2009) 942-948 teach electrospun Nylon nanofiber mats of 50-100 nm diameter and 120 μm thickness. The measured bacteria LRV for non-surface treated fibers is 1.6-2.2. The authors conclude that bacteria removal efficiency of as-spun nanofiber mats is unsatisfactory.

[027] Gopal et al. in Journal of Membrane Science 289 (2007) 210-219, teach electrospun polyethersulfone nanofiber mats, wherein the nanofibers have a diameter of about 470 nm, such that the during liquid filtration the mats act as a screen to filter our particles above 1 micron and as a depth filter for particles under 1 micron.

[028] D. Aussawasathien et al. in Journal of Membrane Science, 315 (2008) 11-19, teach electrospun nanofibers of 30-110 nm diameter used in removal of polystyrene particles (0.5-10 μm diameter).

[029] It would be desirable to have a reliable electrospun nanofiber filter medium suitable for >99.9999% (LRV > 6) removal of retroviral particles, while simultaneously achieving high permeability. These nanofiber mats would have three advantages over traditionally used virus removal membranes: (1) higher permeability as a result of higher porosity, (2) free-standing nature, (i.e., no supporting microporous structure is required), and (3) potential to be used in single layer format. The latter two advantages offer considerably greater flexibility in the design and validation of virus filtration devices.

WHAT IS CLAIMED IS:

1. A method of removing retroviruses from a liquid sample comprising the steps of:

a) providing a liquid sample containing retroviruses,

b) providing a porous nanofiber containing filtration medium having a retrovirus Log Reduction Value (LRV) greater than about 6, a porosity from about 80% to about 95%, and a liquid permeability greater than about 100 LMH/psi, wherein the nanofiber has a fiber diameter from about 10 nm to about 100 nm, and

c) passing the liquid sample containing the retroviruses through the filtration medium resulting in the full retention of retroviruses.

2. The method of claim 1, wherein the filtration medium comprises a mean flow bubble point, as tested with isopropanol, from 100 to 150 psi.

3. The method of claim 1, wherein the filtration medium comprises a thickness from about 1 µm to about 500 µm.

4. The method of claim 1, wherein (he filtration medium comprises a thickness from 1 µm to 50 µm.

5. The method of claim 1, wherein the filtration medium is formed by a process selected from the group consisting of electrospinning and electroblowing.

6. The method of claim 1, wherein the retrovirus is Human Immunodeficiency Virus (HIV).

7. The method of claim 1, wherein the retrovirus is Human T-cell leukemia virus (HTLV).

8. The method of claim 1, wherein the nanofiber comprises a polymer selected from the group consisting of polyimide, aliphatic polyamide, aromatic polyamide, polysulfone, cellulose acetate,

polyether sulfone, polyurethane, poly(urea urethane), polybenzimidazole, polyetherimide, polyacrylonitrile, poly(ethylene terephthalate), polypropylene, polyaniline, poly(ethylene oxide), poly(ethylene naphthalate), poly(butylene terephthalate), styrene butadiene rubber, polystyrene, poly(vinyl chloride), poly(vinyl alcohol), poly(vinylidene fluoride), poly(vinyl butylene) and copolymers, derivative compounds, or blends thereof.

9. The method of claim 1, wherein the nanofiber comprises an aliphatic polyamide.

10. The method of claim 1, wherein the nanofiber comprises a blend of polymers or copolymers.

11. The method of claim 1, wherein the nanofiber is disposed on a porous support.

12. The method of claim 11, wherein the porous support comprises one or more layers selected from the group consisting of spunbonded nonwovens, meltblown nonwovens, needle punched nonwovens, spunlaced nonwovens, wet laid nonwovens, resin-bonded nonwovens, woven fabrics, knit fabrics, paper, and combinations thereof.

13. A porous nanofiber filtration medium for removing retroviruses from a liquid sample, resulting in the full retention of retroviruses, comprising:

a porous nanofiber filtration medium having a retrovirus Log Reduction Value (I.RV) greater than about 6, a porosity from about 80% to about 95%, and a liquid permeability greater than about 100 LMH/psi.

wherein the nanofiber has a fiber diameter from about 10 nm to about 100 nm.

14. The medium of claim 13, further comprising a mean flow bubble point, as tested with isopropanol. from about 100 to about 150 psi.

15. The medium of claim 13, having a thickness from about 1 μm to about 500 μm.

16. The medium of claim 13, having a thickness from about 1 μm to about 50 μm.

17. The medium of claim 13, formed by a process selected from the group consisting of electrospinning and electroblowing.

18. The medium of claim 13, wherein the retrovirus is Human Immunodeficiency Virus (HIV).

19. The medium of claim 13, wherein the retrovirus is Human T-cell leukemia virus (HTLV).

20. The medium of claim 13, wherein the nanofiber comprises a polymer selected from the group consisting of polyimide, aliphatic polyamide, aromatic polyamide, polysulfone, cellulose acetate, polyether sulfone. polyurethane. poly(urea urethane). polybenzimidazole, polyetherimide. polyacrylonitrile. poly(ethylene terephthalate). polypropylene, polyaniline. poly(ethylene oxide). poly(ethylene naphthalate), poly(butylene terephthalate), styrene butadiene rubber, polystyrene, poly(vinyl chloride), poly(vinyl alcohol), poly(vinylidene fluoride), poly(vinyl butylene) and copolymers, derivative compounds, or blends thereof.

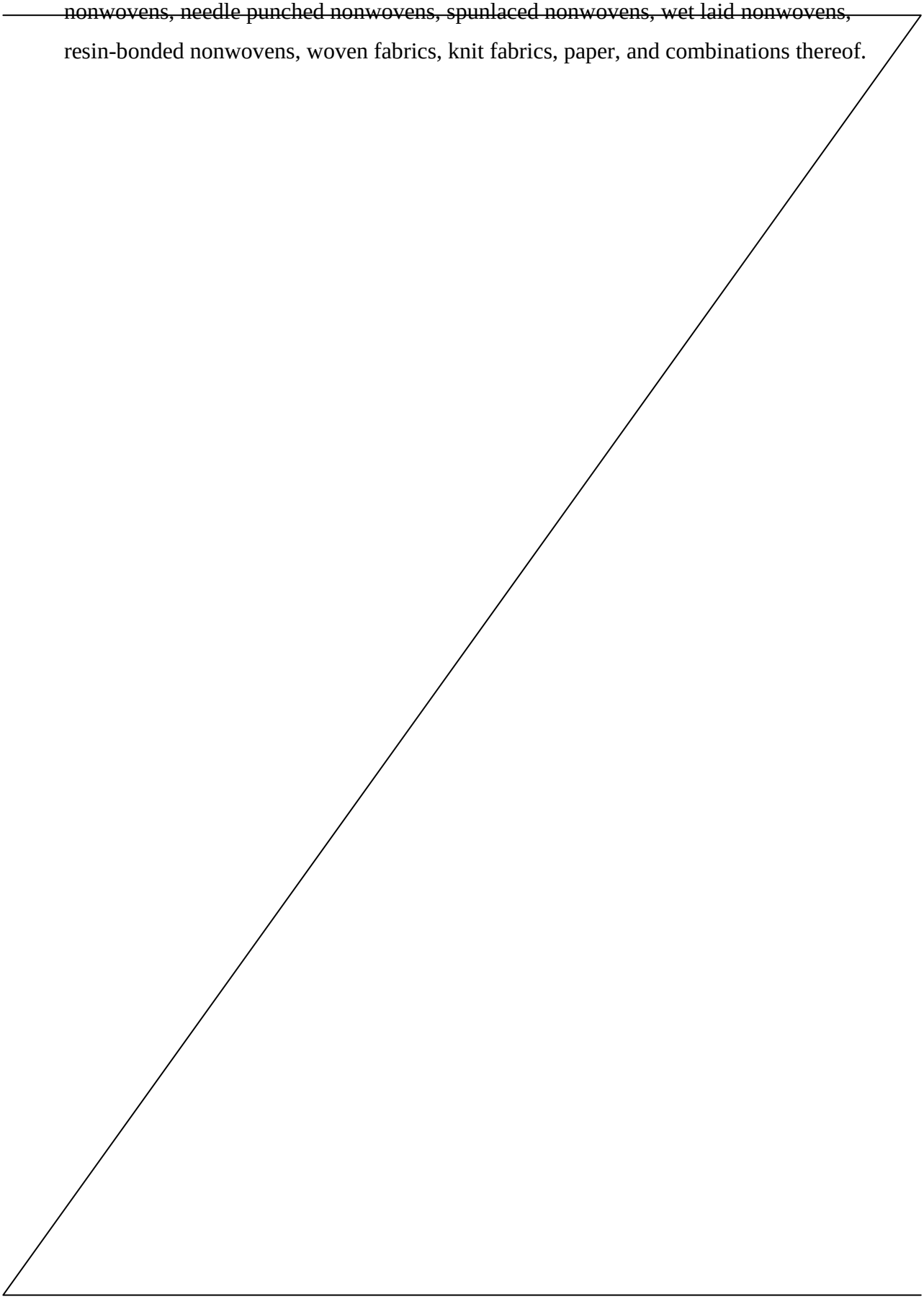
21. The medium of claim 13, wherein the nanofiber comprises an aliphatic polyamide.

22. The medium of claim 13, wherein the nanofiber comprises a blend of polymers or copolymers.

23. The medium of claim 13, wherein the nanofiber is disposed on a porous support.

24. The medium of claim 23, wherein the porous support comprises one or more layers selected from the group consisting of spunbonded nonwovens, meltblown

~~nonwovens, needle punched nonwovens, spunlaced nonwovens, wet laid nonwovens,~~ resin-bonded nonwovens, woven fabrics, knit fabrics, paper, and combinations thereof.



25. A liquid filtration device having a retrovirus LRV greater than about 6 for use in fully retaining retroviruses removed from a liquid sample passing through the device, the filtration device comprising:

a porous electrospun nanofiber filtration medium having a LRV greater than 6;

a porosity from about 80% to about 95%. and a liquid permeability greater than about 100 LMH/psi; and

a porous support, wherein the nano fiber filtration medium is disposed on the porous support and the nanofiber has a fiber diameter from about 10 nm to about 100 nm.

26. The device of claim 25, wherein the electrospun nanofiber filtration medium comprises a thickness from about 10 μm to about 100 μm.

27. The device of claim 25, wherein the electrospun nanofiber filtration medium comprises a thickness from 1 μm to 50 μm.

28. The device of claim 25, further comprising a mean flow bubble point, as tested with isopropanol, from about 100 to about 150 psi.

29. The device of claim 25, wherein the electrospun nanofiber filtration medium comprises a mean pore size from about 0.05 μm to about 3 μm.

30. The device of claim 25, wherein the electrospun nanofiber filtration medium is a polymeric fibrous mat.

31. The device of claim 30, wherein the nanofiber comprises a polymer selected from the group consisting of polyimide, aliphatic polyamide, aromatic polyamide, polysulfone, cellulose acetate, polyether sulfone, polyurethane, poly(urea urethane), polybenzimidazole, polyetherimide, polyacrylonitrile, poly(ethylene terephthalate), polypropylene, polyaniline, poly(ethylene oxide), poly(ethylene naphthalate), poly(butylene terephthalate), styrene butadiene rubber, polystyrene,

poly(vinyl chloride), poly(vinyl alcohol), poly(vinylidene fluoride), poly(vinyl butylene) and copolymers, derivative compounds, or blends thereof.

32. The device of claim 25, wherein the nanofiber comprises an aliphatic polyamidc.

33. The device of claim 25, wherein the nanofiber comprises a blend of polymers or copolymers.

34. The device of claim 25, wherein the nanofiber is disposed on a porous support.

35. The device of claim 25, wherein the porous support comprises one or more layers selected from the group consisting of spunbonded nonwovens, meltblown nonwovens. needle punched nonwovens, spun laced nonwovens, wet laid nonwovens, resin-bonded nonwovens. woven fabrics, knit fabrics, paper, and combinations thereof.

36. The device of claim 25, wherein the retrovirus is retrovirus is Human Immunodeficiency Virus (HIV).

37. The device of claim 25, wherein the retrovirus is Human T-cell leukemia virus (HTLV).

WHAT IS CLAIMED IS

1. A porous electrospun nanofiber filtration medium for removing retroviruses from a liquid sample, resulting in the retention of retroviruses, comprising:

a porous electrospun nanofiber filtration medium having a retrovirus Log Reduction Value (LRV) greater than 6, a porosity from 80% to 95%, a liquid permeability greater than 100 LMH/psi, and a mean flow bubble point, as tested with isopropanol from 120 to 140 psi,

wherein the nanofiber has a fiber diameter from 10 nm to 30 nm.

2. The medium of claim 1 having a thickness from 1 μm to 500 μm.

3. The medium of claim 1 having a thickness from 1 μm to 50 μm.

4. The medium of claim 1 wherein the retrovirus is Human Immunodeficiency Virus (HIV) or Human T-cell leukemia virus (HTLV).

5. The medium of claim 1 wherein the nanofiber comprises a polymer selected from the group consisting of polyimide, aliphatic polyamide, aromatic polyamide, polysulfone, cellulose acetate, polyether sulfone, polyurethane, poly(urea urethane), polybenzimidazole, polyetherimide, polyacrylonitrile. poly(ethylene terephthalate), polypropylene, polyaniline, poly(ethylene oxide), poly(ethylene naphthalate), poly(butylene terephthalate), styrene butadiene rubber, polystyrene, poly(vinyl chloride), poly(vinyl alcohol), poly(vinylidene fluoride), poly(vinyl butylene) and copolymers, or blends thereof.

6. The medium of claim 1 wherein the nanofiber comprises an aliphatic polyamide.

7. The medium of claim 1 wherein the nanofiber comprises a blend of polymers or copolymers.

8. The medium of claim 1 wherein the nanofiber is disposed on a porous support.

9. The medium of claim 8 wherein the porous support comprises one or more layers selected from the group consisting of spunbonded nonwovens, meltblown nonwovens, needle

punched nonwovens, spunlaced nonwovens, wet laid nonwovens, resin-bonded nonwovens, woven fabrics, knit fabrics, paper, and combinations thereof.

10. A method of removing retroviruses from a liquid sample comprising the steps of:

a) providing a liquid sample containing retroviruses,

b) providing a porous electrospun nanofiber filtration medium as claimed in any one of claims 1 to 9; and

c) passing the liquid sample containing the retroviruses through the filtration medium resulting in the retention of retroviruses.

11. The method of claim 10 wherein the retrovirus is Human Immunodeficiency Virus (HIV) or Human T-cell leukemia virus (HTLV).

12. A liquid filtration device having a retrovirus LRV greater than 6 for use in retaining retroviruses removed from a liquid sample passing through the device, the filtration device comprising:

i) a porous electrospun nanofiber filtration medium as claimed in any one of claims 1 to 9; and

ii) a porous support,

wherein the electrospun nanofiber filtration medium is disposed on the porous support.

13. The device of claim 12 wherein the electrospun nanofiber filtration medium comprises a mean pore size from 0.05 μm to 1 μm.

14. The device of claim 12 wherein the electrospun nanofiber filtration medium is a polymeric fibrous mat.

15. The device of claim 12 wherein the porous support comprises one or more layers selected from the group consisting of spunbonded nonwovens, meltblown nonwovens. needle punched nonwovens, spun laced nonwovens, wet laid nonwovens, resin-bonded nonwovens, woven fabrics, knit fabrics, paper, and combinations thereof.

16. The device of claim 12 wherein the retrovirus is retrovirus is Human Immunodeficiency Virus (HIV) or Human T-cell leukemia virus (HTLV).